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Climate of the Past

A 70-yr record of oxygen-18 variability in an ice core from the Tanggula Mountains, central Tibetan Plateau

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Abstract. A 33 m ice core was retrieved from the Tanggula Mts, central Tibetan Plateau at 5743 m a.s.l. in August 2005. Annual average δ^{18}O values were determined for the upper 17 m depth (14.6 m w.eq.), representing the time series since the mid-1930s. Data are compared to previous results of an ice core from Mt. Geladaindong, 100 km to the northwest, for the period 1935–2003. During the time 1935–1960, δ^{18}O values differed by 2–3‰ between the two ice cores, with generally lower ratios preserved in the Tanggula 2005 core. Differences in interannual variability and overall average ratios between the two study locations highlight the spatially variable climate controls on ice core isotope ratios within the boundary of monsoon- and westerly-impacted regions of the central Tibetan Plateau. Average annual net accumulation was 261 mm w.eq. for the period 1935–2004. The overall average δ^{18}O value was −13.2‰ and exhibited a statistically significant increase from the 1935–1969 average (−13.7‰) to the 1970–2004 average (−12.6‰). Despite the observed increase in isotope ratios, isotopic temperature dependence was not evident, based on comparison with long-term data from meteorological stations to the north and southwest of the study location. Lack of correlation between average δ^{18}O values and temperature is likely due to monsoon influence, which results in relatively greater isotopic depletion of moisture during the warm season. Evidence of monsoon impacts on precipitation in the central Tibetan Plateau has been previously documented, and statistically significant negative correlation (r=−0.37, p <0.01) between the annual average ice core δ^{18}O values and North India monsoon rainfall was observed for the period 1935–2004. Although the δ^{18}O data agree well with the monsoon rainfall amount, no significant correlation was observed between the core accumulation and the monsoon rainfall amount. Previous model and observational results suggest monsoon impact on δ^{18}O in precipitation may extend beyond the immediate extent of heavy monsoon rainfall, reaching the central Tibetan Plateau. These results provide evidence that the δ^{18}O variability at this study location may be sensitive to southern monsoon intensity.

1 Introduction

High elevation ice cores from the mid- and low-latitude regions have been instrumental for reconstructing environmental records. With sufficiently high elevation to preserve annual accumulation, the mountain regions of the Tibetan Plateau (TP) provide an ideal location to examine interannual variability of geochemical signals preserved in snow and ice. Stable isotopes in ice cores have been widely used as a paleothermometer in this region. However, moisture sources and water vapor recycling differ between the northern and southern TP (Tian et al., 2001a), resulting in spatially and temporally variable isotope-temperature relationships. The main moisture in the northern TP is dominated by strong continental recycling with high evaporation and mainly convective precipitation. Moisture in the southern TP is mainly provided by the Indian monsoon, with humid oceanic origins such as the Bay of Bengal (Tian et al., 2001b). Isotopic dependence on temperature is established for continental locations in the northern TP, far-removed from monsoon moisture (Yao et al., 1996). In those areas, the most depleted isotope ratios are associated with accumulation during the coldest temperatures and the least depleted ratios arrive with warm-season

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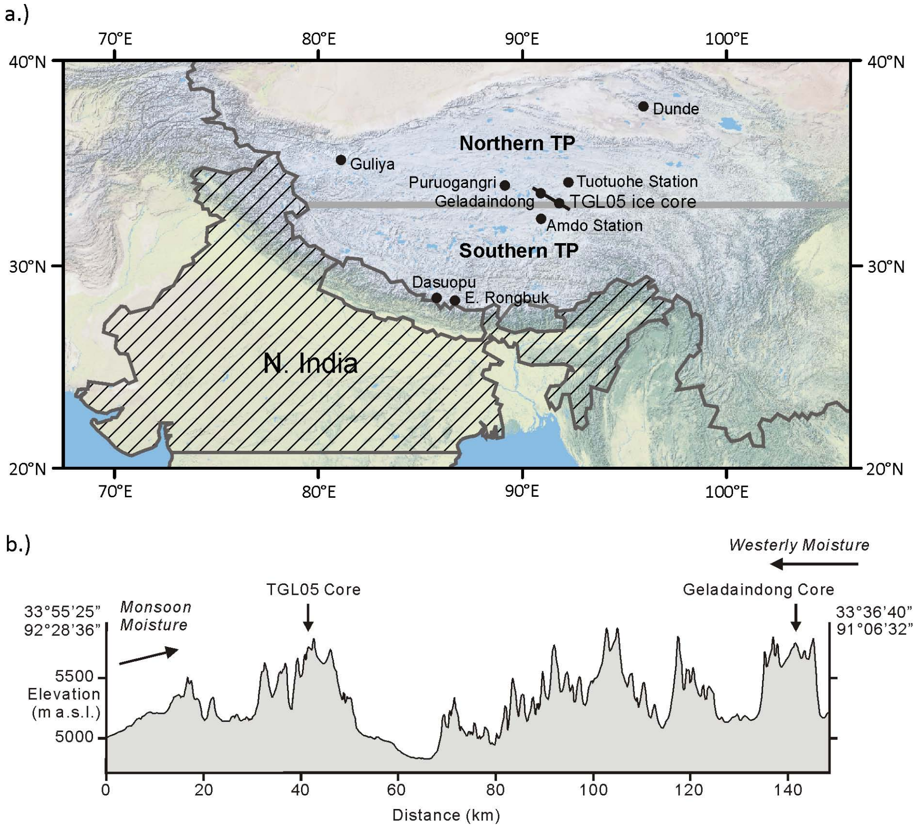

Fig. 1. **(a)** Ice core and meteorological station locations. Black line indicates elevation profile used for **(b)**. Approximate region of North India precipitation (Sontakke et al., 2008) shown with hatched fill, 33° N latitude shown as grey line. Borders are shown for reference only and are not meant to denote true political boundaries. (b) Elevation profile sketch from SE to NW within the Tanggula Mts.

moisture, recognized as the typical isotopic temperature dependence observed at continental locations (Rozanski et al., 1993). For example, ice cores from the Puruogangri ice field (Thompson et al., 2006; Yao et al., 2006), and from the Guliya and Dunde ice caps (Yao et al., 1996) correlate well with instrumental temperature data. Locations of those cores are shown in Fig. 1a for reference. Areas in the southern TP exhibit the opposite relationship; more depleted monsoon moisture arrives during the warm season resulting in a negative isotope-temperature correlation (Araguas-Araguas et al., 1998; Dahe et al., 2000; Kang et al., 2002; Tian et al., 2001c; 2003, Vuille et al., 2005). Westerly atmospheric circulation dominates the central TP in winter, with westerly surface winds split into northern and southern branches. In summer, the westerly jet is pushed northward with the maximum extent of the South Asian Monsoon associated with the characteristic trough east of the Indian subcontinent (Vuille et al., 2005). These interacting circulation systems provide converging atmospheric moisture to the central TP from vastly different source regions with distinct transport histories. It is important to also note the influence of temporal scales associated with ice core isotope-temperature relationships in monsoon regions. As outlined by Yu et al. (2008), ice core δ^{18}O values in the southern TP are impacted by monsoon seasonality on short time scales, but may still match temperature trends on longer time scales. This relationship may be understood considering the underlying relationship between monsoon circulation and temperature. For example, Bradley et al. (2003) demonstrated the importance of Pacific SSTs in controlling the isotopic signal in the Dasuopu ice core from the central Himalayas (Fig. 1a). It is therefore necessary to evaluate central TP locations more thoroughly, in order to determine the possibility of using a particular ice core for temperature reconstructions in this region.

Previous results of reconstructed precipitation since AD 1600 from ice cores in the northern and southern TP (Fig. 1a) indicated a distinct phase reversal from the north to the south, with distinct climatic conditions impacting the two regions of the TP (Yao et al., 2006). Differences between the northern and southern TP are also apparent from the opposing relationship between temperature and δ^{18}O in each region. Increasing positive correlation between temperature and δ^{18}O from the southern to the northern TP indicates a gradual northward weakening of monsoon activity (Yu et al., 2008), with the Tanggula Mts acting as the main orographic barrier to the southeast monsoon (Tian et al., 2001c). Although long-term isotope precipitation data is sparse within the central TP, prior results (Ohata et al., 1994;

Tian et al., 2003; Zhang et al., 2007b) have reported the influence of monsoon precipitation manifesting as depleted δ^{18}O values in precipitation during the main monsoon period from June through September (JJAS). It has been suggested that the main latitudinal zone where tropical monsoon circulation interacts with westerly-dominated air masses coincides with the Tanggula Mts, around 33° N (Tian et al., 2001b; Thompson et al., 2006). The ice core presented here was drilled at 33°7′4.26″ N, 92°5′26.16″ E, elevation 5743 m a.s.l., directly within this boundary region (Fig. 1).

In this paper, we present results from the upper 17 m of a 33 m ice core retrieved from the south-central Tanggula Mts (subsequently referred to as TGL05). Annual average δ^{18}O variability representing the time period 1935–2004 is presented in comparison to ground-based temperature and precipitation records, in order to evaluate the relative importance of temperature and isotopically depleted monsoon moisture at this study location. Previous results (Kang et al., 2007) from an ice core near Mt. Geladaindong (33°34′37.8″ N, 91°10′35.3″ E, elev. 5720 m a.s.l.), approximately 100 km to the northwest of the TGL05 ice core presented here (Fig. 1), provided a comparison for the time period 1935–2004. In addition, a 14 m ice core from the Tanggula Mts (33°04′ N, 92°05′ E) provided a comparison for the time period 1940–1990 (Yao et al., 1995). A significant isotope-temperature correlation was observed for the Mt. Geladaindong ice core based on comparison with records from five meteorological stations in the vicinity (Kang et al., 2007). However, relatively more depleted summer isotope ratios in the Geladaindong core also revealed impacts from monsoon moisture (Zhang et al., 2007b), demonstrating the relationships at multiple temporal scales suggested by Yu et al. (2008). The annual variability of δ^{18}O preserved in the TGL05 core extends the spatial coverage of ice core records in the central TP, where paleo-records remain sparse.

2 Methods

In August 2005, a 33 m depth ice core was retrieved from the upper Longxia Zailongba glacier accumulation zone. The core was in excellent condition throughout and lacked brittle ice zones. Core sections were transported frozen to the State Key Laboratory of Cryospheric Science in Lanzhou and processed at 5 cm resolution for geochemical analysis. Oxygen isotope ratios and major ion concentrations were determined at the Key Laboratory of Tibetan Environment Changes and Land Surface Processes, (CAS). Oxygen isotope ratios were determined using a continuous-flow IRMS system, with similar referencing strategies as described by Werner and Brand (2001). Sample vials were auto-flush-filled with 0.3% CO_2 in He and analyzed after equilibration with a Finnigan Delta Plus MAT 253 IRMS and GasBench II/GC PAL system. Care was taken to avoid possible contamination that can result from insufficient flush-fill time or extended storage (Paul and Skrzypek, 2006). Sample isotope ratios were measured as the average of five peaks per sample and are reported in standard delta notation (δ) vs. Vienna Standard Mean Ocean Water (V-SMOW). Analytical δ^{18}O precision for the upper 17 m (n=327) was 0.09‰, based on maximum deviation of external standards for all runs. Concentrations of major ions were measured from co-registered samples using Dionex chromatographs (ICS2000 and ICS2500 for cations and anions, respectively). Cations were analyzed using a CS12 4 mm column, 200 µL loop, isocratic 18 mM MAS eluent, and anions with an AS11-HC 4 mm column, 500 µL loop, isocratic 25 mM KOH eluent. Detection limits for measured cations and anions was less than 1 µg/L. Analysis of field blanks showed that contamination during transport, processing, and analysis was negligible.

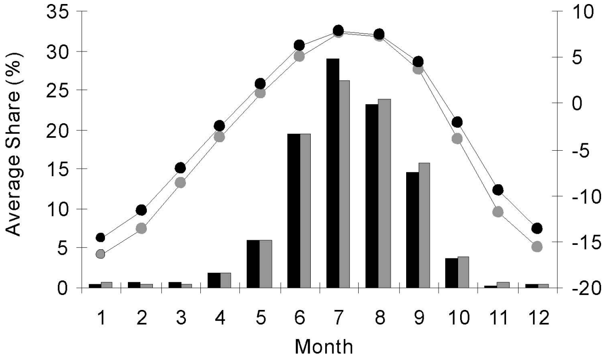

Fig. 2. Monthly distribution of precipitation (bars) and temperature (lines) for Tuotuohe (in black) and Amdo (in grey) meteorological stations.

Temperature data from two stations (Figs. 1a, 2) were used for comparison with ice core δ^{18}O results. One station is located to the north of the drill site (Tuotuohe), while the other station is to the southwest (Amdo). Meteorological station locations and the average temperature and precipitation for the corresponding time period are provided in Table 1. Monthly averages were obtained from Monthly average temperature and total precipitation data were obtained from the daily measurements reported by the meteorological administration. In order to evaluate possible monsoon influence on the TGL05 ice core δ^{18}O values, annual average isotope ratios were compared to the average monsoon precipitation (JJAS) in North India (Sontakke et al., 2008) for the period 1935–2004. The precipitation sum of the four homogenous rainfall regions north of 21° N (North Mountainous India, Northwest India, North Central India, and Northeast India) defined by Sontakke et al. (2008) was used since these monsoon-impacted regions are directly adjacent to the TP (Fig. 1a).

Table 1. Meteorological station summary data. P_T is average total precipitation, T_A is average annual temperature, and T_M is average monsoon (JJAS) temperature.

Station	Time Period	Latitude	Longitude	Elev (m a.s.l.)	P_T (mm)	T_A (°C)	T_M (°C)
Tuotuohe	1957–2004	34°13′ N	92°26′ E	4533	278	−4.1	5.8
Amdo	1966–2004	32°21′ N	91°06′ E	4800	440	−2.8	6.4

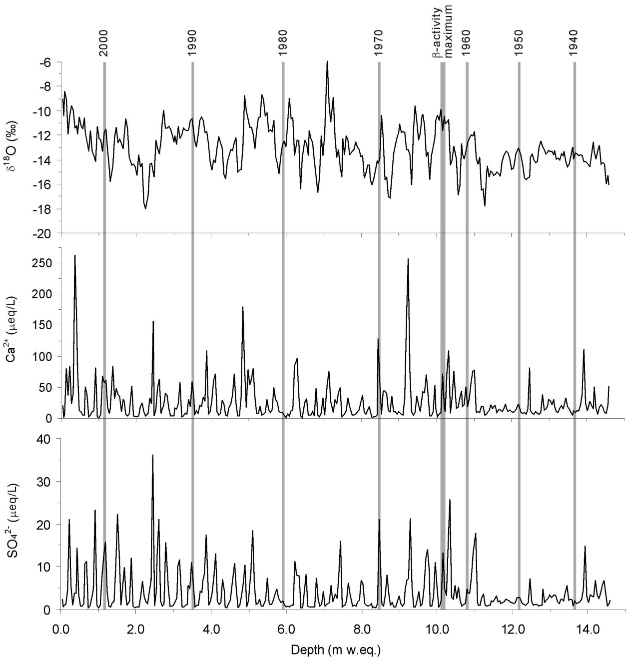

Fig. 3. δ^{18}O profile for the upper 14.6 m w.eq. depth shown with SO_4^{2-}, Ca^{2+}, and established depth-age scale.

3 Results

The ice core depth-age scale was established based on the layer counted peaks in major ions, as δ^{18}O isotope values did not exhibit discernable annual peaks due to insufficient winter accumulation. Well-preserved peaks in ion concentrations likely resulted from the combination of dry and wet deposition, with the former occurring mainly during the cold, dry winter, and the latter associated with relatively lower concentrations in wet deposition during the summer. Insufficient amount of winter precipitation made seasonal isotope variations unapparent at the 5 cm sampling resolution. The periodic component of δ^{18}O and SO_4^{2-} data did not reveal a significant power at the expected annual frequency using traditional Fourier analysis. Similar results reported for an ice core from Svalbard were explained by a large standard deviation in accumulation rates that can mask the annual signal in frequency space (Pohjola et al., 2002). The standard deviation of annual accumulation in the TGL05 core was 60 mm w.eq., compared to the annual average of 261 mm, suggesting a similar possible effect. Thus, annual identification was based on the layer counted peaks in SO_4^{2-} and Ca^{2+} to 14.6 m w.eq. depth, representing the time period from 1935 to 2004 (Fig. 3). Although a portion of the lower core exhibits relatively lower ion concentrations, identifiable peaks were apparent when examined at the appropriate scale. Partial melt may be possible during extremely warm years, but is assumed to refreeze directly without significant impact on the preserved signal. This is evidenced by the well preserved peaks in ion concentrations and large range in isotope values in the upper portion of the core, corresponding to years with maximum recorded monthly and annual average temperatures (Fig. 4d). Although significant melt within the snow and firn pack is expected to have a smoothing effect on geochemical constituents, previous results indicated that periodic melt may have little actual effect on the isotopic signal in an ice core (Pohjola et al., 2002). Smoothing of the geochemical data in the TGL05 core was not apparent during the most notable warm years from 1998–2003 (Fig. 4d), when annual average isotope values exhibited a large range of nearly 4‰ (Fig. 4b) and a sample range of over 6‰ (Fig. 3). The established depth-age scale was verified from the depth of maximum β-activity corresponding to the 1963 Northern Hemisphere maximum in atmospheric tritium concentrations, which was within +/−1 yr of the layer-counted age at 10.2 m w.eq. depth (Fig. 3).

Average annual accumulation for the represented time period was 261 mm w.eq., as determined from the ratio of the annual layer thickness to the flow-modeled thickness multiplied by the surface accumulation rate (Haefeli, 1961; Nye, 1963; Henderson et al., 2006). In comparison to previous mass balance data for the Dongkemadi Glacier in the Tanggula Mts (Fujita et al., 2000; Pu et al., 2008), the TGL05 core accumulation data closely match the variations in mass balance for the period 1998–2002. Both the annual accumulation in the TGL05 core and the Dongkemadi Glacier mass balance reveal a decreasing trend for the period 1989–2002 (Pu et al., 2008). However, considerable differences were noted between the two records for the period 1989 to 1998. Differences in mass balance and accumulation data for two different locations are expected, considering the impacts of both temperature and precipitation on glacier mass balance. Compared to the total annual precipitation at Tuotuohe and Amdo stations, the TGL05 annual accumulation showed insignificant correlation with total annual precipitation. Greater spatial coverage of observational precipitation data is needed to further quantify local precipitation variability in this region.

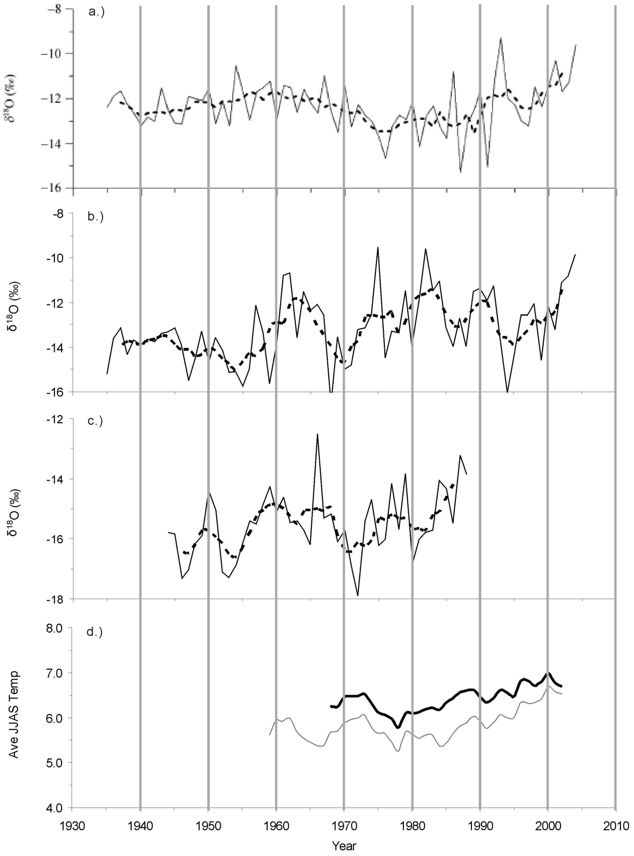

Fig. 4. (a) δ^{18}O values from the Geladaindong ice core (Kang et al., 2007). Annual averages are depicted with solid lines, 5-yr running means with dashed lines. **(b)** Same as (a) for the TGL05 ice core. **(c)** Same as (a) for a previous Tanggula ice core (Yao et al., 1995); note the more depleted δ^{18}O scale **(d)** Average JJAS temperatures recorded at Tuotuohe (black line) and Amdo stations (grey line).

Annual average δ^{18}O isotope values representing the period 1935–2004 are summarized in Table 2, and are presented in Fig. 4 for comparison to annual δ^{18}O values from the Geladaindong ice core (Kang et al., 2007), a previous ice core from the Tanggula Mts (Yao et al., 1995), and average JJAS temperatures recorded at Tuotuohe and Amdo stations. In comparison to the Geladaindong ice core (Fig. 4a), a greater amount of interannual variability was preserved in the TGL05 ice core (Fig. 4b). Differences in the two records are most apparent prior to 1970. Despite similar elevations, isotope ratios are generally 2–3‰ lower in the TGL05 ice core prior to 1960, after which time ratios generally increase until peaking in the early- to mid-1960s. Subsequent to 1970, a general trend of increasing isotope ratios is present in both cores. Greatest increase in the TGL05 isotope ratios is observed for the period 1994–2004 (Fig. 4b), while maximum increase in the Geladaindong ice core began slightly earlier (Fig. 4a). Trends in the TGL05 ice core isotope ratios agree well with previous results from a 14 m ice core (Yao et al., 1995), approximately 5 km to the south. General consistency is most apparent from the 5-yr running means, with both cores revealing lowest isotope values prior to the mid-1950s, increasing to the early- to mid-1960s maximum, and further increase subsequent to 1970 (Fig. 4b, c). During the 1980s, the cores show different trends in annual δ^{18}O values. While the previous Tanggula ice core δ^{18}O values exhibit a general decrease from 1980 to 1989, the TGL05 core decreases in the early 1980s, then increases from the mid-1980s until the early-1990s.

Table 2. δ^{18}O summary statistics (‰) for the upper 17 m ice core depth, representing the time period 1935–2004.

n	327
max	−5.9
min	−18.1
median	−13.0
mean	−13.2
σ	1.8

Average annual δ^{18}O value in the TGL05 ice core increased from −13.7‰ for the period 1935–1969 to −12.6‰ for the period 1970–2004, a significant increase at the α=0.01 level. Since the mid-1950s, the TP has undergone significant warming (Yao et al., 1995). To investigate the degree to which increasing isotope ratios in the TGL05 ice core reflect increasing temperatures, annual average ratios were compared to average JJAS temperatures recorded at two meteorological stations in the vicinity. Tuotuohe and Amdo stations both showed consistent temperature variations for the respective recording times, with the greatest increase in JJAS temperatures observed since the mid-1980s (Fig. 4d). Average JJAS temperatures were used for comparison since these months accounted for 83–86% of the total annual precipitation during their respective recording times (Fig. 2).

The timing of temperature increase at the two meteorological stations is earlier compared to the δ^{18}O increase observed in the Geladaindong and in the TGL05 ice cores. Correlations between the δ^{18}O values in the TGL 05 ice core and the average JJAS station temperatures at Amdo and Tuotuohe stations were compared to the isotope-temperature correlations for the Geladaindong ice core (Kang et al., 2007) for the same time period. Correlations between δ^{18}O values and average JJAS temperatures at Amdo and Tuotuohe are presented in Table 3 for both cores. No significant correlation between the TGL05 annual average δ^{18}O value and average JJAS temperature was observed for either of the two stations. Even more revealing is the lack of correlation between the 5-yr smoothed average δ^{18}O value and 5-yr smoothed JJAS average station temperature, given the consistent variation of the 5-yr running mean temperatures at the two stations (Fig. 4d). Significant correlation for the 5-yr running means, compared to the annual correlations was noted for

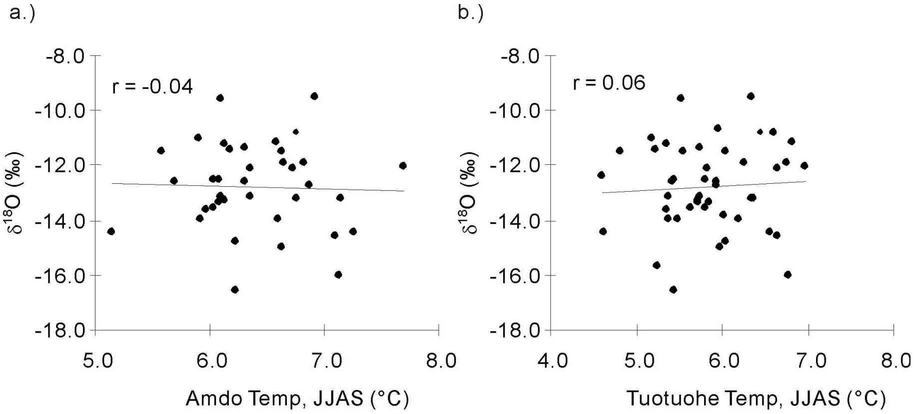

Fig. 5. Scatterplot of annual average δ^{18}O values and average JJAS temperature recorded at Amdo (1966–2003) and Tuotuohe (1958–2003) meteorological stations.

Table 3. Correlations between δ^{18}O values and average JJAS station temperatures for annual and 5-yr running means in the TGL05 ice core, and for the Geladaindong ice core (Kang et al., 2007). Reported values are from 1966–2003 for Amdo station, 1958–2003 for Tuotuohe station.

		Tuotuohe	Amdo
Annual average	TGL05	0.06	−0.04
	Geladaindong	0.23	0.32
5-yr smoothed	TGL05	−0.09	−0.15
	Geladaindong	0.57	0.78

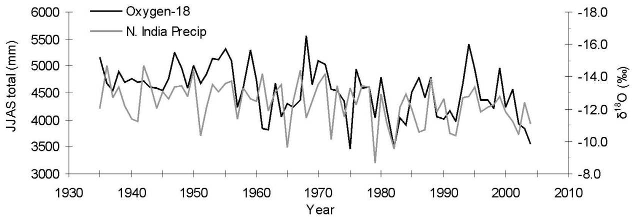

Fig. 6. Annual average δ^{18}O variability plotted with North India monsoon rainfall (Sontakke et al., 2008). Note the reversed isotope scale.

the Geladaindong core. Since the main precipitation season of JJAS is based on a long-term average, isotope ratios in the TGL05 core were also compared to precipitation-weighted temperatures. Precipitation-weighted temperatures did not reveal a significant correlation when compared on an annual average or on a 5-yr running mean basis. The lack of agreement between TGL05 ice core isotope ratios and average JJAS temperatures (Fig. 5), as well as precipitation-weighted annual temperatures, indicate limited use of the δ^{18}O values as a single parameter for temperature reconstructions at this location, and suggest other controlling factors such as contribution of depleted monsoon had a greater influence on the preserved isotopic ratios.

A comparison was made with the amount of North India monsoon precipitation (Sontakke et al., 2008) to investigate possible influence of monsoon moisture. A significant correlation was revealed between δ^{18}O values and North India precipitation for both the annual averages ($r=-0.37$, $p<0.01$), and for the 5-yr running means ($r=-0.72$, $p<0.01$). Figure 6 demonstrates the agreement between δ^{18}O variability and the amount of North India precipitation on an annual basis. Since the isotope values in Fig. 6 are plotted with a reversed scale, peaks in North India precipitation may be identified with greater isotopic depletion. A general decrease in North India precipitation since the 1960s can be observed in Fig. 6, consistent with the increase in ice core isotope values. A scatterplot of the 5-yr running mean TGL05 ice core δ^{18}O values and North India precipitation illustrates the significant correlation and negative regression-line slope characteristic of monsoon moisture (Fig. 7). Results indicate years with greater amount of North India precipitation were typically associated with greater isotope depletion in the TGL05 ice core. Since the δ^{18}O values in the TGL05 ice core revealed a significant relationship to North India precipitation, a comparison was made to annual average δ^{18}O values from two ice cores belonging to the monsoon-dominated region, the Dasuopu and E. Rongbuk ice cores (Fig. 1a). Annual average δ^{18}O values in the TGL05 core showed no significant correlation with either the Dasuopu core (1935–1996) or the E. Rongbuk ice core (1962–2004). Ice cores from the southern TP have been widely documented to record monsoon variability (e.g. Dahe et al., 2000; Davis et al., 2005; Thompson et al., 2000). Thus, we do not infer the North India JJAS rainfall to represent a monsoon index, but rather present the noteworthy comparison to the δ^{18}O values in the TGL05 ice core. Given the low accumulation (261 mm w.eq. yr^{-1} average) we

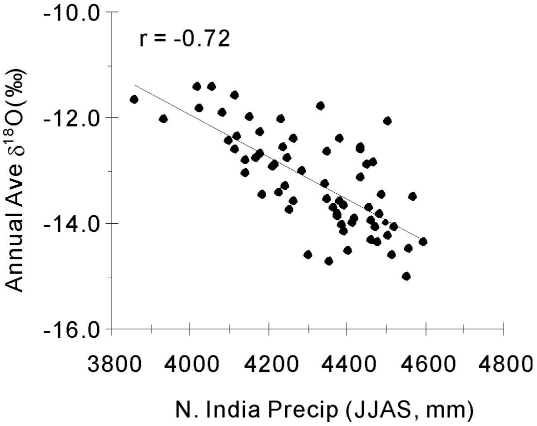

Fig. 7. Scatterplot of 5-yr running mean δ^{18}O values and total North India precipitation, 1935–2004.

also acknowledge minimal monsoon influence on the overall amount of moisture at the study location. No statistically significant correlation was observed between the annual average δ^{18}O values and the annual accumulation in the TGL05 core. Vuille et al. (2008) suggested that effects of monsoon moisture on isotope ratios may be observed in areas where local precipitation is not directly affected by monsoon variability, due to increased rainout and distillation processes during transport. These results provide some assessment of monsoon impact on the isotope ratios in this ice core, although the basis of the observed relationship between North India precipitation and δ^{18}O values ratios at this study location remains unclear. Future analysis of δD may further elucidate the relationship in the context of moisture source regions, transport, and recycling.

4 Discussion

The TGL05 ice core revealed lower annual δ^{18}O values and greater interannual variability compared to the Geladaindong ice core. Relatively more depleted isotope ratios were most apparent prior to the mid-1950s, although both cores revealed increasing trends since the 1970s. Isotopic temperature dependence was previously established for the Geladaindong ice core by Kang et al. (2007). However, the TGL05 ice core did not reveal significant correlation between δ^{18}O values and JJAS temperature during the same time period. Contrasting results between the two study locations indicate relatively high local variation of δ^{18}O signals. These differences suggest variable moisture sources, transport, and climatic conditions are impacting the two locations, although the relative importance of each of these factors is not discernable from the single isotope parameter. Good agreement between the TGL05 ice core isotope record and a shallow ice core 5 km to the south (Yao et al., 1995) indicate these cores were more impacted by depleted monsoon moisture compared to the Geladaindong ice core, 100 km to the northwest. The cause of the lower δ^{18}O values in the previous Tanggula ice core (Yao et al., 1995) compared to the TGL05 core is not apparent from comparison with the instrumental record, given limited spatial coverage of meteorological data. If the region is situated within the northern-most extent of the monsoon influence on the δ^{18}O isotopic signal, it is possible even a small local variation in latitude could impact annual average δ^{18}O values. However, given the close proximity of the drill site locations this explanation seems insufficient to fully explain the local differences. The relationship between δ^{18}O values and North India precipitation amount exhibited a significant negative slope that would be expected for an area impacted by monsoon moisture, although influence on actual amount of precipitation appears minimal. Evidence of a weakening monsoon in the central Himalayas was presented by Duan et al. (2004) based analysis of the Dasuopu ice core accumulation record in conjunction with rainfall records from the surrounding regions. Within the central TP, it is plausible that a weakening monsoon, and therefore the associated supply of isotopically depleted moisture during the warm season, may have a similar impact on the observed δ^{18}O values as that of increasing temperature. If the central TP region is at the northern-most extent of monsoon impacts, a weakening monsoon may be coupled with greater isotopic temperature dependence. Since the main accumulation arrives during the warm season, increased temperature dependence may also be responsible for less depleted annual average δ^{18}O values compared to those associated with monsoon moisture. Separating the variability associated with monsoon impacts from the isotopic temperature dependence is not likely with the single parameter of δ^{18}O. Results are in accordance with previous research (Vuille et al., 2008) suggesting an area upstream from monsoon moisture, such as the central TP, may experience isotopic influences from transport and distillation processes without significant impact on the amount of moisture. Given the distance of the study location from the main region of heavy monsoon precipitation, we suggest a true monsoon signal may be obscured by temperature effects and local precipitation variability. However, monsoon moisture may provide a general source of depleted atmospheric water vapor recognizable in the isotopic signal in the central TP despite the lack of significant impact on the amount of annual accumulation.

5 Conclusions

Annual average δ^{18}O values were determined for the upper 17 m depth of an ice core from the Tanggula Mts, representing the time period 1935–2004. Results contribute to the spatial coverage of isotope data from ice cores from the Tibetan Plateau. The lack of correlation between δ^{18}O values and station temperatures suggests limited application of isotopes as a paleo-thermometer for the TGL05 ice core. Differences and similarities among previous ice core data from the central TP highlight the variable nature and local controls on δ^{18}O in precipitation. Significant negative correlation between TGL05 ice core δ^{18}O values and North India precipitation provides evidence that the southeastern Tanggula Mts may receive depleted moisture during the maximum extent of the Indian Summer Monsoon. Although the main moisture may be blocked in the southern TP by the Himalayas, these results provide further evidence that the impact of monsoon circulation on δ^{18}O values in precipitation extends beyond the southern TP into portions of the central TP as well. Future analysis of δD will provide a means to quantify moisture sources, transport distances, and continental recycling at this study location. Additional ice cores from the central TP are needed in order to more fully understand the glacio-geochemical records in the context of westerly and monsoon circulation system interactions and variability.

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